Computer Use and Habitual Spinal Posture in Australian Adolescents

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SYNOPSIS

Objective. Computer use is common in adolescents, and there is evidence that adolescent spinal posture alters during computer use. However, it is unknown if computer use and habitual postures are associated. The objective of this study was to evaluate associations between adolescent computer use and habitual postures.

Methods. Eight hundred eighty-four adolescents (408 females, 476 males, mean age, 14.0 years, standard deviation, 0.2) completed a questionnaire assessing weekly computer use. Habitual spinal posture was assessed by photographic analysis while standing and sitting.

Results. Computer use was associated with adolescent habitual postures. In males, increased computer use was associated with increased head flexion and neck flexion. In females, increased computer use was associated with increased lumbar lordosis.

Conclusions. The amount of weekly computer use was associated with changes in habitual spinal postures, and these depended on gender. These associations may result from temporary computer postures leading to adaptive neuromusculoskeletal changes, though further multivariate and longitudinal studies are needed to confirm causality. As some habitual posture changes may place a greater strain on the musculoskeletal system, computer use by adolescents should be viewed as a possible health concern.

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Computer use has grown steadily since the development of microcomputer systems in the early 1970s, and has become almost ubiquitous in affluent countries.[1] Sixty-four percent of adults in the U.S. used a computer in 2003, and use by younger people is even more prevalent.[1–3] Ninety-nine percent of Australian children between the ages of 11 and 14 used a computer in 2003,[4] and children in the U.S. now spend in excess of 60 minutes a day in front of a computer.[5] This recent surge in computer use has given rise to concerns that time spent using a computer may adversely affect health and development in adolescents.[6,7]

Computer use may influence physical health indirectly by displacing more vigorous physical activities.[8] Evidence in support of this displacement has been found in negative associations between vigorous physical activity and computer use in young children,[9] although other studies have identified positive associations between physical activity and computer use in adolescents.[10–12] Computer use has also been associated with musculoskeletal disorders of the neck and upper limb, such as repetitive strain injury, with posture thought to have an etiological role.

The use of computers influences instantaneous spinal postures in both adults[13–15] and adolescents.[8,13–18] Such temporary alterations in posture may in themselves be important, influencing the degree of spinal loading[16] and, thus, possibly being a factor in reports of greater spinal pain in adult[19–22] and adolescent[23] computer users. However, the effects of computer use on *habitual* postures have not been documented in either adults or adolescents. Changes in habitual posture could be of greater consequence than the transient changes occurring during computer use, as sustained changes in posture may lead to more prolonged periods of altered spinal loading. This sustained change may exaggerate any adverse effects of altered spinal loading due to reduced opportunities for tissue regeneration.[24] Increased flexion or extension can alter loading on spinal tissues and lead to pain. Therefore, any systematic change in posture associated with computer use may be important. In an earlier laboratory study, we found posture differences between genders when using computers.[16] Therefore, the influence of computer use on habitual postures may be gender-specific.

The aim of this study was to test the hypothesis that the duration of computer use is associated with habitual postures in male and female adolescents.

METHODS

Subjects

Data were collected from adolescents participating in the "Raine" child health study. This study—a long-term project on a range of child health and development issues—began as a pregnancy cohort in which 2,979 women were enrolled between 16 and 20 months of gestation from the antenatal clinics at King Edward Memorial Hospital for Women, Perth, Western Australia, between 1989 and 1991. The children have been followed at birth, and at ages 1, 2, 3, 5, 8, 10, and 14. A comparison of this cohort with the general population of Western Australia utilizing the Western Australian Maternal and Child Health Research Database at the Telethon Institute for Child Health Research[25] found the sample to be reasonably representative, with the exception of higher at-risk pregnancies.

Cross-sectional data from 884 adolescents—408 females, 476 males, mean age, 14.0 (standard deviation [SD], 0.2)—are presented in this article. There were no exclusion criteria. The mean height was 1.64 meters (SD, 0.08) and mean weight was 57.0 kilograms (SD, 12.4).

Procedure

Adolescents completed a questionnaire on a laptop at the assessment center with the help of a research assistant. The questionnaire contained 130 questions concerning a broad range of physical, medical, nutritional, psychosocial, and developmental issues. The question relevant to computer use is recorded in this article, with the possible responses in parentheses.

> On average, how many hours a week do you usually use a computer, e.g., play video or computer games, use the Internet, or chat online (including school days and weekends)? (None at all, Up to 7 hours a week, 7–14 hours per week, 14–21 hours per week, or 21 or more hours per week)

While a simple survey question only provides a gross estimate, this approach is widely used due to the limitations of other exposure assessment methods. The full child questionnaire took about one hour to complete, and the aforementioned question occurred in the first half.

A physical assessment of the child carried out after the questionnaire was used to measure anthropometric factors, muscle performance, coordination, and spinal posture during sitting and standing. The latter was assessed through standard photographic analysis procedures.[13,14]

Retroreflective markers were placed on the right outer canthus, right tragus, 7th cervical (C7) and 12th thoracic (T12) spinous processes, anterior superior iliac spine, and greater trochanter. Lateral photographs were taken with each child sitting on a stool (adjusted to their popliteal height) during three different static postures: looking straight ahead, looking down at their lap, and in a slumped position. Marker points were digitized using the Peak Motus (Peak Performance Technologies, Centennial, CO) motion analysis system, and angles were calculated (Figure 1).

Data analysis

Statistical analysis was carried out with SPSS Version 13.0.[26] Only cross-sectional bivariate analyses have been reported in this article. Alpha probability level was set at $p<0.05$ for all comparisons. Chi-squared (χ^2) analysis was used to examine the presence and strength of the relationship between gender and computer use. Differences in postural variables between males and females were examined using independent means *t*-tests after testing for equal variances using Levene's test. The relationship between posture and computer use was considered separately in males and females due to the large gender differences in the posture variables and the different patterns of postural variation with computer use observed in males and females during the data screening process.

Visual inspection of the plots of several of the posture variables against computer use suggested a nonlinear relationship. To assess the type and degree of association between posture variables and computer use, a series of analyses of variance with polynomial trend analysis were performed, with each posture variable as the dependent variable, and weekly computer use as the independent variable. Residual analysis was performed to confirm the validity of these models. Additionally, two planned contrasts were specified to compare groups with (*1*) low or no use (<7 hours per week) to moderate to high use (≥7 hours per week) and (*2*) moderate use (7–14 hours per week) to high use (>14 hours per week).

Figure 1. Definitions of postural angles

Name	*Angle definition*
Head flexion	Line of canthus to tragus with respect to vertical (measured from vertical above intersect)
Neck flexion	Line of tragus to C7 with respect to vertical (measured from vertical above intersect)
Thoracic flexion	Line of C7 to T12 with respect to vertical (measured from vertical above intersect)
Pelvic tilt	Line of greater trochanter to ASIS with respect to vertical (measured from vertical above intersect)
Cranio-cervical angle	Angle between line of canthus to tragus and line of tragus to C7 (measured anterior to intersect)
Cervico-thoracic angle	Angle between line of tragus to C7 and line of C7 to T12 (measured anterior to intersect)
Trunk angle	Angle between line of C7 to T12 and line of T12 to greater trochanter (measured posterior to intersect)
Lumbar angle	Angle between line of T12 to ASIS and line of ASIS to greater trochanter (posterior angle)

C7 = 7th cervical spinous process

T12 = 12th thoracic spinous process

ASIS = anterior superior iliac spine

Ethics

The study was approved by the Human Research Ethics Committees of Curtin University of Technology and Princess Margaret Hospital, both in Perth, Western Australia.

RESULTS

Computer use

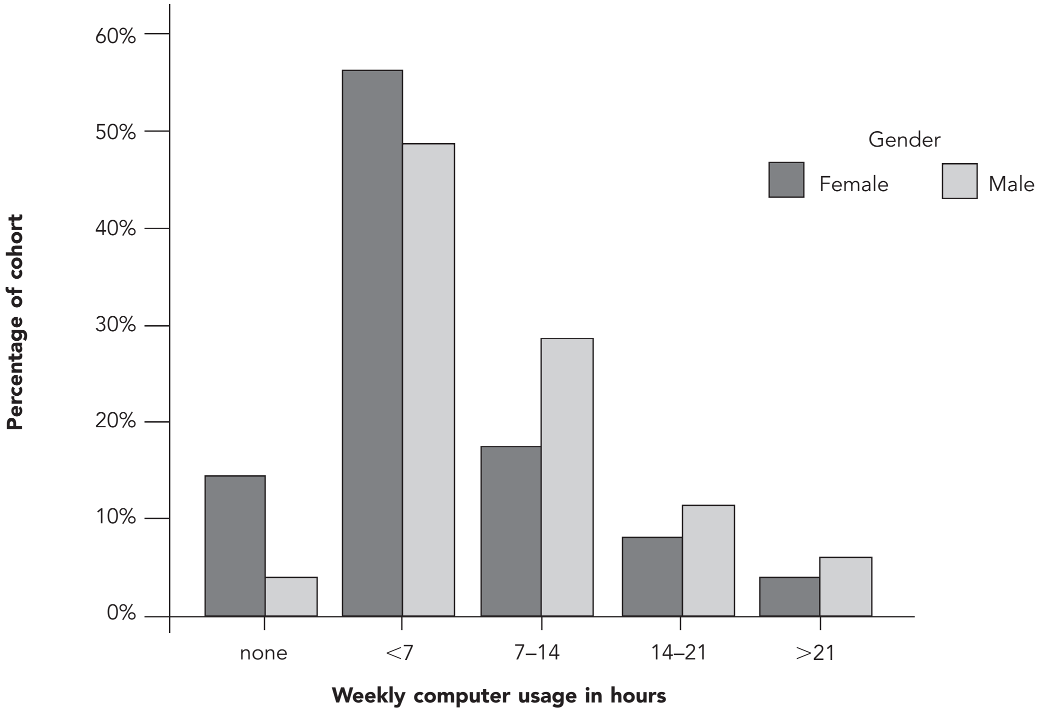
Eight hundred eighty-one adolescents provided a valid response to the questionnaire item: 9.1% (80) adolescents reported not using a computer at all, 52.3% (463) adolescents used a computer for seven hours or less each week, 23.7% (209) adolescents used a computer for 7–14 hours a week, 10.2% (90) adolescents used a computer for 14–21 hours a week, and 4.4% (39) adolescents used a computer for more than 21 hours a week.

A weak but significant association was identified between gender and weekly computer use ($\chi^2=49.1$, $p<0.001$, Cramér's V = 0.236). Examination of the standardized residuals revealed that females were more likely to not use a computer and males were more likely to have high levels of computer use (Figure 2).

Gender differences in posture

There were considerable differences in posture variables between males and females while sitting looking down (Table). Female adolescents had significantly less head flexion, neck flexion, and thoracic flexion, and significantly more anterior pelvic tilt than males. When sitting looking down, female adolescents also

Figure 2. Self-reported weekly computer usage for female (n=408) and male (n=479) adolescents



had a more flexed cervico-thoracic angle and more extended trunk and lumbar angles. Female adolescents also displayed a higher cranio-cervical angle than males while sitting looking down.

Similar differences in posture variables were observed between males and females when sitting looking straight ahead, when sitting in a maximal slumped position (Table), and when standing (data not shown). Females also displayed significantly greater changes in range of these variables when moving from sitting looking straight ahead and slumped sitting (Table).

Posture and computer use

Males: sitting looking straight ahead. A number of significant associations between computer use and posture variables were observed in males while sitting looking straight ahead. There was a significant difference in mean head flexion angle between different levels of computer use ($F_{[\text{degree of freedom (df) } 4,463]}=2.70$, $p=0.030$), with males reporting little to no computer use having significantly reduced head flexion angle as compared to those males with moderate to high computer use ($t_{[\text{df } 463]}=2.17$, $p=0.031$). Trend analysis revealed a significant but weak linear component to the relationship between computer use and head flexion angle with greater average head flexion angle in those groups with higher computer use ($F_{[\text{df } 1,463]}=4.94$, $p=0.027$, $\eta^2=0.010$), but also a weak significant quadratic relationship ($F_{[\text{df } 1,463]}=4.07$, $p=0.044$, $\eta^2=0.008$), with the greatest average head flexion angle in the group using computers for 7–14 hours per week (Figure 3).

While there were no significant differences in mean neck flexion angle between different levels of computer use observed in males sitting looking straight ahead ($F_{[\text{df } 4,463]}=1.82$, $p=0.123$), a significant weak linear trend was observed, with average neck flexion angle increasing with computer use ($F_{[\text{df } 1,463]}=4.65$, $p=0.032$, $\eta^2=0.010$).

There was a significant difference in mean cranio-cervical angle between different levels of computer use in males while sitting looking straight ahead ($F_{[\text{df } 4,463]}=2.67$, $p=0.032$). Males with moderate computer use displayed a reduced cranio-cervical angle compared to males with high computer use ($t_{[\text{df } 1,463]}=2.62$, $p=0.009$). Trend analysis revealed a weak but significant quadratic relationship ($F_{[\text{df } 1,463]}=6.97$, $p=0.009$, $\eta^2=0.015$), with the lowest mean cranio-cervical angle in the moderate users (7–14 hours per week).

No significant associations between levels of computer use and the posture variables cervico-thoracic

Table. Sitting posture angles and change in angles (°) in males and females (mean [standard deviation])

Posture angle	Males (n=468)	Females (n=401)	Gender difference t_{df}	p-value[a]
Sitting looking down				
Head flexion	107.6 (13.2)	104.9 (12.5)	3.06_{870}	**0.002**
Neck flexion	70.8 (11.7)	66.8 (9.4)	5.46_{867}	<**0.001**
Cranio-cervical angle	143.2 (11.3)	141.8 (11.4)	1.73_{867}	0.084
Cervico-thoracic angle	137.5 (9.3)	131.6 (8.0)	9.93_{867}	<**0.001**
Thoracic flexion	28.7 (11.2)	19.0 (9.1)	13.96_{867}	<**0.001**
Trunk angle	240.4 (11.8)	227.9 (10.7)	16.32_{867}	<**0.001**
Anterior pelvic tilt	0.5 (16.1)	8.7 (12.9)	8.25_{870}	<**0.001**
Lumbar angle	135.4 (18.8)	125.4 (15.6)	8.47_{870}	<**0.001**
Sitting looking straight ahead				
Head flexion	71.9 (9.8)	71.8 (8.6)	0.03_{870}	0.978
Neck flexion	52.8 (9.7)	50.9 (6.9)	3.28_{867}	**0.001**
Cranio-cervical angle	160.9 (11.9)	159.1 (11.3)	2.30_{867}	**0.022**
Cervico-thoracic angle	153.1 (7.4)	145.7 (6.7)	15.51_{867}	<**0.001**
Thoracic flexion	26.4 (10.7)	17.1 (8.7)	13.82_{867}	<**0.001**
Trunk angle	238.1 (11.7)	225.8 (10.5)	16.24_{867}	<**0.001**
Anterior pelvic tilt	0.6 (16.1)	9.2 (12.8)	8.53_{870}	<**0.001**
Lumbar angle	135.0 (18.9)	125.0 (15.5)	8.43_{870}	<**0.001**
Sitting slumped				
Head flexion	154.3 (13.9)	151.2 (15.8)	3.13_{870}	**0.002**
Neck flexion	109.3 (13.7)	106.8 (14.0)	2.72_{867}	**0.007**
Cranio-cervical angle	135.1 (10.2)	135.6 (10.6)	-0.73_{867}	0.466
Cervico-thoracic angle	110.5 (9.9)	108.6 (10.8)	2.74_{867}	**0.006**
Thoracic flexion	40.2 (10.7)	35.8 (9.2)	6.31_{867}	<**0.001**
Trunk angle	253.3 (7.8)	248.2 (7.4)	9.79_{867}	<**0.001**
Anterior pelvic tilt	−5.3 (15.5)	−3.1 (12.9)	-2.26_{870}	**0.024**
Lumbar angle	141.7 (18.1)	137.7 (15.4)	3.52_{870}	<**0.001**
Change in angle between sitting looking straight ahead and slumped sitting				
Head flexion	82.5 (16.1)	79.3 (17.4)	-2.77_{870}	**0.006**
Neck flexion	56.6 (13.0)	55.9 (13.6)	-0.79_{867}	0.428
Cranio-cervical angle	25.8 (11.1)	23.5 (10.7)	3.15_{867}	**0.002**
Cervico-thoracic angle	42.7 (10.7)	37.1 (11.7)	7.29_{867}	<**0.001**
Thoracic flexion	13.8 (10.3)	18.7 (10.2)	-7.08_{867}	<**0.001**
Trunk angle	15.1 (9.0)	22.3 (9.1)	-11.68_{867}	<**0.001**
Anterior pelvic tilt	6.0 (8.6)	12.3 (8.2)	-11.03_{870}	<**0.001**
Lumbar angle	6.8 (7.8)	12.7 (8.2)	11.00_{870}	<**0.001**

[a]Significant *p*-values are in bold.

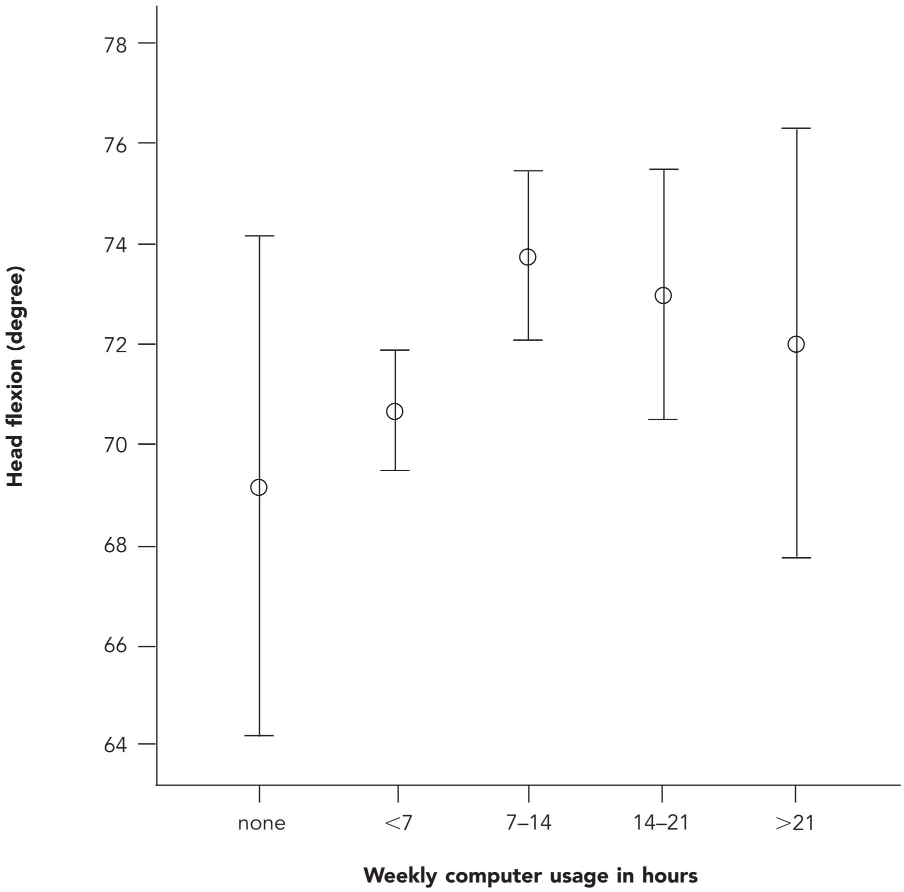
t = t statistic

df = degree of freedom

angle, trunk angle, pelvic tilt, or lumbar angle were observed in males while sitting looking straight ahead, although a weak linear trend was observed with thoracic flexion, with increasing levels of computer use associated with increasing thoracic flexion, but this trend did not reach statistical significance ($F_{[df\ 1,460]}= 3.09$, $p=0.079$, $\eta^2=0.007$).

Males: sitting looking down. A weak linear trend was observed between levels of computer use and head flexion and neck flexion angles, with increasing levels of computer use associated with increased flexion angle, but this trend did not reach statistical significance ($F_{[df\ 1,463]}=3.45$, $p=0.064$, $\eta^2=0.007$; $F_{[df\ 1,463]}=3.12$, $p=0.078$, $\eta^2=0.007$). While there were no significant differences in mean thoracic flexion angle between different levels of computer use observed in males sitting looking down ($F_{[df\ 4,460]}=1.22$, $p=0.303$), a significant but weak linear trend was observed, with thoracic flexion increasing with computer use ($F_{[df\ 1,460]}=3.89$, $p=0.049$,

Figure 3. Head flexion (mean ±95% confidence interval) across different levels of weekly computer usage in males sitting looking straight ahead

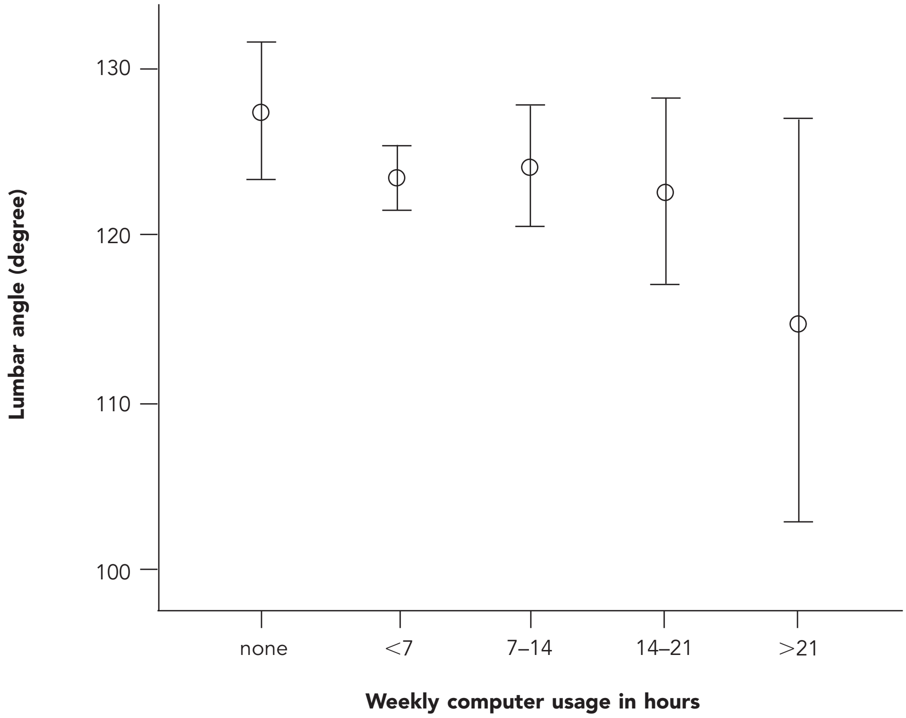


η^2=0.008). No significant associations between levels of computer use and cranio-cervical angle, cervicothoracic angle, trunk angle, pelvic tilt, or lumbar angles were observed in males sitting looking down.

Females: sitting looking straight ahead. Females sitting looking straight ahead demonstrated a weak but significant linear trend between levels of computer use and lumbar angle, with increasing levels of computer use associated with increased lumbar lordosis ($F_{[df\,1,396]}$=4.14, p=0.043, η^2=0.010) (Figure 4). Females with little to no computer use displayed a significantly greater mean lumbar angle as compared with those females with moderate to high computer use ($t_{[df\,396]}$=2.26, p=0.025). A similar trend was observed with regard to pelvic tilt, with increasing levels of computer use associated with increasing anterior pelvic tilt, but this trend did not reach statistical significance ($F_{[df\,1,396}$=2.85, p=0.092, η^2=0.007). No significant associations between levels of computer use and any other posture variables were observed.

Females: sitting looking down. Similar associations between pelvic posture and computer use were observed in females sitting looking down as with those observed sitting looking straight ahead. Females sitting looking down demonstrated a weak but significant linear trend between levels of computer use and lumbar angle, with increasing levels of computer use associated with decreasing lumbar angle ($F_{[df\,1,396]}$=4.78, p=0.029, η^2=0.012). Again, a similar trend was observed with regard to pelvic tilt, with increasing levels of computer use associated with increasing anterior pelvic tilt, but this trend did not reach statistical significance ($F_{[df\,1,396]}$= 3.72, p=0.054, η^2=0.009). No significant associations between levels of computer use and any other posture variables were observed.

Figure 4. Lumbar angle (mean ±95% confidence interval) across different levels of weekly computer usage in females sitting looking straight ahead



Males and females: sitting slumped. No significant associations between levels of computer use and any posture variables measured while subjects were sitting slumped were observed, with the exception of lumbar angle in females. Again, females demonstrated a weak but significant linear trend between levels of computer use and lumbar angle, with increasing levels of computer use associated with decreasing lumbar angle (more lordotic) ($F_{[df\ 1,396]}=4.68$, $p=0.031$, $\eta^2=0.012$).

Change in range from sitting looking straight ahead to sitting slumped. There was no relationship between computer use and the change in range of any posture variables between sitting looking straight ahead and slumped sitting in either males or females. Computer use was not associated with the proximity to end of range of relaxed sitting postures.

DISCUSSION

Almost 91% of the 14-year-olds in this study reported usually using a computer each week. Though substantial, this statistic was lower than the 95% to 99% expected.[4,27] The lower prevalence may be due to differences in the nature of the computer use questions or to characteristics of these adolescents. We intend to investigate the psychosocial and socioeconomic characteristics of the non-computer users in future studies to determine if these factors are associated with lack of computer use.

The actual amount of computer use per week—with almost 40% using the computer more than seven hours a week—was similar to reports in two studies from the U.S.,[5,28] but lower than another U.S. study[27] and a study from Hong Kong.[10] The greater computer use in adolescent males reflects one previous report.[29] In contrast, Ho et al.[10] noted that although there were more males than females who had ever used a computer, the overall duration of usage did not differ. Despite this variation, it is clear that adolescent computer use is both significant and widespread. Its effects on adolescent development are, therefore, worthy of investigation.

This article is the first report of associations between computer use and habitual sitting posture in adolescents. These associations were weak, with computer use never explaining more than 2% of the variation in the posture angles. Assuming causality, this article suggests that computer use is just one of many determinants of habitual posture. Moreover, the variation in posture angles between computer use categories was small, often only amounting to a few degrees. However, our group has also shown associations between small posture variations and neck/shoulder pain, suggesting that even small changes in habitual posture may be clinically important.

Possible mechanisms for computer use to influence habitual postures

Computer use might affect habitual postures directly, with transient postural changes during computer use leading to more permanent changes in habitual postures through adaptive neuromusculoskeletal changes.[30] Because it is likely that the degree of such adaptations would depend on the total duration of the stimulus,[31] it might explain the mainly linear relationship observed between hours of use and some habitual postures.

Although it could be argued that the relatively low durations of computer use would be unlikely to lead to noticeable adaptations, there is evidence that very small stimuli can induce lasting physical changes. For example, McKay et al.[32] showed that three sets of 10 jumps per week, and twice-weekly physical education lessons incorporating jumping activities, can increase bone mineral density in children. If this mechanism is valid, one explanation for the weak association between computer use and habitual posture may be the wide variety of instantaneous postures assumed when using computers.

Computer use could also affect habitual postures indirectly, for example, via physical activity or pain. High levels of computer use may lead to reduced physical activity,[8] with a subsequent reduction in muscle endurance that could affect habitual posture.[33] High levels of computer use may increase neck pain,[23,34] which may, in turn, influence posture. Our group has found associations between chronic neck pain and increased lumbo-pelvic extension in adolescent females, although the cause-and-effect relationship of this finding is not yet clear.

While we consider it unlikely that habitual posture may influence computer use, other factors such as poor social functioning might lead to both greater amounts of computer use and changes in posture, thus giving rise to a spurious relationship. Further prospective work involving a variety of physical, lifestyle, and psychosocial factors is necessary to better understand the nature of these relationships. However, if computer use does have a causal effect on habitual posture, this association is of interest, as any activity that has long-term effects on the musculoskeletal system is of potential concern. Moreover, limited research in adolescents[35,36] and more extensive studies in adults[37–41] have suggested that habitual posture and spinal pain are associated, implying that changes in habitual posture may lead to spinal pain.

Gender differences in postural associations

Male and female adolescents differed completely in their associations between habitual posture and computer use. Increased computer use was associated with increased head and neck flexion in males and lumbar extension in females. Possible reasons for the gender variation may be differences in anthropometry, tasks performed, the amount of computer posture variation, inherent motor control, and social expectations. All these factors could influence computer posture and, therefore, possibly habitual posture.

Briggs et al.[16] showed that standing height influences neck flexion during computer use, and children's computer workstations are often not adjusted for height.[18] Males in the current study were 4 cm taller than females, suggesting that they may have needed greater head and neck flexion to view the computer, while females may have extended their trunk to raise their eye height. However, sitting height may not differ in 14-year-olds.[42]

Male and female adolescents are known to have different computer activity patterns, with females spending a greater proportion of time on e-mails and educational games, and males a greater proportion of time on noneducational games.[27] These different tasks may have different postural requirements. Although there is no direct evidence that these specific tasks induce different computer postures, there is some evidence that keyboarding and using the mouse involve different postures in children.[18] In addition, noneducational games are associated with more backache in children,[27] which may suggest a different posture during this activity. Task differences may also be compounded by gender differences in terms of variation in postures. In adults, there is evidence that female computer operators have fewer breaks.[43]

Quadratic relationship for head flexion in males

The quadratic relationship between habitual head flexion and computer use in males suggests that characteristics of the high computer use group (>14 hours) may alter computer use effects. When comparing the male high users against the other males, there were no differences in coordination, hand strength, standing long jump ability, back endurance, or aerobic fitness, but the male high computer users did have a greater prevalence of neck/shoulder pain ever (χ^2=6.095, p=0.014). It is therefore possible that the high male users adjusted their habitual postures in response to this pain.

Consistency of postural associations across positions
Many of the changes in postural angles associated with computer use were consistent across different sitting conditions. For example, greater computer use was related to greater lumbar extension in females when looking ahead, looking down, and slumped sitting. This trend probably relates to a high level of correlation between spinal angles across these three different sitting positions in both males and females. However, these associations tended to persist when standing.

The association between head flexion and computer use in males that was observed in the sitting position was similar to that observed during standing, and the association between lumbar angle and computer use in females observed in the sitting position was similar to that observed during standing. These consistent associations indicate that computer use may exert an influence on habitual spinal postures across many functional positions, and may augment any adverse effects through reduced opportunities for regeneration.[24]

Limitations
Assessing computer use by questionnaire, while widely used, provides only a crude, gross estimate. Using technical measurement whereby computer use is logged by software is not practical for adolescents who have access to multiple computers—at home, school, friends' houses, and community libraries. Activity recording by an independent observer is also not suitable for a large survey of adolescents. Self-report methods are, therefore, the only currently viable methods, with activity diaries placing a greater burden on responders than a single question. While questionnaire estimates may be crude, they are unlikely to be biased. Therefore, the association found in the current analysis is likely to be real.

This article presents cross-sectional relationships, which provide only weak causal evidence. Computer use and posture were not previously assessed in the Raine cohort, but we are currently collecting this information at 16 years of age and will prospectively examine the relationship of computer use at 14 years with habitual posture at 16 years.

Only bivariate analyses are reported in this article, despite a wide range of physical, lifestyle, and psychosocial variables potentially influencing posture and being available from this cohort. Multivariate analyses are planned; however, we believe these should be built on an understanding of simpler relationships.

CONCLUSIONS

Computer use was associated with changes in adolescent habitual postures, and it is possible that these changes were due to a carry-over effect from temporary changes in posture during computer use. These changes varied between males and females, although reasons for this relationship are yet to be determined. The postural changes also tended to be consistent across sitting and standing, which may imply a greater impact on health. This study, therefore, provides evidence that computer use in adolescence may alter developing neuromusculoskeletal systems.

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